

Ten years at war: Comprehensive analysis of amputation trends

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BACKGROUND:	While multiple studies have examined amputations that have occurred during the current conflicts in Iraq and Afghanistan, none of these studies have provided an overarching characterization of all of these injuries.
METHODS:	A retrospective study of all major extremity amputations sustained by US Service Members from January 2001 through July 30, 2011, was performed. Data obtained from these amputees included amputation level(s), mechanism of injury, time to amputation, Injury Severity Score (ISS), age, rank, number of trauma admissions, and number of troops deployed.
RESULTS:	There were 1,221 amputees who met inclusion criteria. These amputees sustained a total of 1,631 amputations. The number of amputations performed each year has increased dramatically in 2010 (196) and the first half of 2011 (160) from 2008 (105) and 2009 (94). The number of amputations performed per every 100 traumatic admissions (3.5/14) and the number of amputations per 100,000 deployed troops (2/14) has also increased in 2010 and the first half of 2011. Most amputations occurred at the transtibial (683, 41.8%) and transfemoral (564, 34.5%) levels. Thirty percent of the amputees (366) sustained multiple amputations, and 14% of all amputations (228) performed involved the upper extremity. There were 127 amputees (10%) who underwent their amputation more than 90 days after the date of injury.
CONCLUSION:	The number of amputations occurring during the current Iraqi and Afghanistan conflicts has increased in 2010 and the first half of 2011. Most amputations involve the lower extremities, and there is a much higher percentage of amputees who have sustained multiple amputations during current operations than previous conflicts. (<i>J Trauma Acute Care Surg.</i> 2012;73:S438-S444. Copyright © 2012 by Lippincott Williams & Wilkins)
LEVEL OF EVIDENCE:	Epidemiologic study, level IV.
KEY WORDS:	Extremity amputations; Iraq; Afghanistan; transtibial; transfemoral.

During Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND), many US Military Service Members have sustained traumatic injuries, particularly to their extremities.^{1,2} While improved protective gear and medical treatment principles have helped decrease mortality,^{3,4} it has been speculated that this decrease in mortality has led to an increased number of surviving Service Members with amputated limbs.^{5,6} These amputations not only make it very difficult for Service Members to return to active duty^{7,8} but also can be life altering,⁹ costly,^{3,10} and exceptionally difficult to manage.^{11,12}

There have been numerous studies published examining major amputations caused by extremity trauma during the OIF, OEF, and OND conflicts.¹³⁻¹⁹ However, while these studies have unquestionably increased understanding of these injuries, limitations in size and variations in study design and statistical

analysis have left gaps in our knowledge regarding the amputations that have been sustained by the US Military during the past 10 years of OIF, OEF, and OND. The goal of this study is to analyze and characterize the all of the US Military amputees from the start of the OEF/OIF/OND conflicts in 2001 through July 2011. Supplemental Digital Content 1 (see Table, Supplemental Digital Content 1, <http://links.lww.com/TA/A214>) lists the common abbreviations that are used throughout this article.

PATIENTS AND METHODS

This study was conducted under a protocol reviewed and approved by our institutional review board. The Military Amputation Database (MAD) (Bethesda, Maryland) was queried to identify all major extremity amputations (MEAs) sustained by Service Members that occurred between October 1, 2001, and July 30, 2011. A MEA was defined as an amputation proximal to the carpals or tarsals of a limb.²⁰ The following data were extracted from the database for each Service Member: age at injury, date of injury, date of first amputation, rank, amputation level, and a very brief narrative history of the injuring event and acute medical care provided.

The MAD provided us with 1,316 amputees, of which 1,221 met our inclusion criteria and were used in our analysis. These names were then cross-referenced within the Joint Theater Trauma Registry (JTTR) at the US Army Institute of Surgical Research (Fort Sam Houston, Texas). This registry contains medical treatment data on Service Members that are obtained from the battlefield and each treatment facility where they are treated. Using the names identified from the MAD,

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This study commenced after being approved by the US Army Institute of Surgical Research Institutional Review Board.

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the JTTR was queried for gender, military operation (OIF, OEF, or OND), dominant injury cause, dominant injury type, battle versus nonbattle injury, branch of service, Injury Severity Score (ISS), and extremity Abbreviated Injury Scale (AIS) score for each Service Member. Dominant injury type was listed as explosive device, gunshot wound (GSW), motor vehicle accident (MVA), helicopter crash, or machinery/equipment. Dominant injury cause was categorized as penetrating, blunt, burn, or other. The AIS uses the following scale to score the severity of injury in each of nine body regions: 0 = no injury, 1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, and 6 = fatal. There is no AIS score of 6 for the extremity subcategory, making 5 the maximum score for an extremity injury. The AIS is used to calculate the ISS on a scale from 0 to 75 with a score greater than 8 being considered serious or fatal.¹⁹

The Defense Manpower Data Center provided the casualty statistics for US Service Members involved in OIF, OEF, and OND from October 1, 2001, through July 30, 2011. Casualties were defined as any person who is lost to the organization by reasons having been declared dead, missing, captured, interned, wounded, injured or seriously ill.²¹ These casualties were further categorized based on the Service Member's branch of service, gender, hostile versus nonhostile injury type, rank, and age. The Defense Manpower Data Center

also provided statistics for those Service Members who were killed in action (KIA), died of wounds (DOW), or sustained an accidental/other death during OEF, OIF, and OND. These deaths were grouped by month and categorized as being hostile or nonhostile and by branch of service. Service Members who were KIA died before reaching a medical treatment facility, whereas those service members who DOW were alive when they arrived to a medical treatment facility before dying of their wounds. Combining those Service Members who were KIA and those who DOW provided the number of combat-related deaths sustained during the conflicts. The case fatality rate would be calculated by dividing the combat-related deaths by the number of deaths and the number of nonfatally wounded Service Members.

The JTTR provided the number of Service Members who were admitted at a Role IIB or III facility for a traumatic injury for each month from October 1, 2001, through July 30, 2011. According to the JTTR definition, a traumatic injury was defined as "an injury that was less than 72 hours old and required a Service Member to be admitted as an inpatient within a medical treatment facility or as an injury that lead to a Service Member's death." Records of how many Service Members from each branch of service were deployed each month in Iraq and Afghanistan from October 2005 through July 2011 were obtained from the Office of the Surgeon

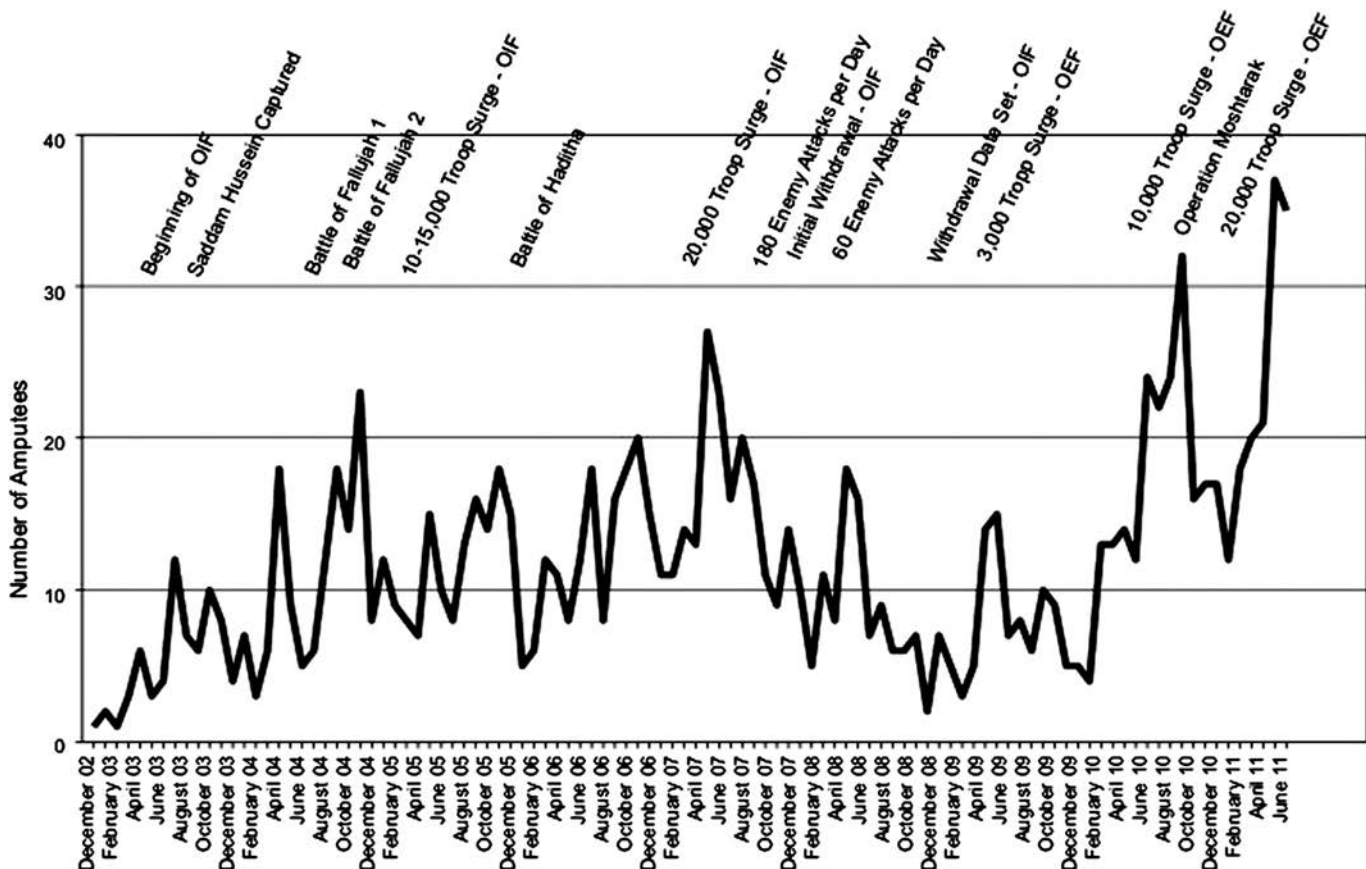


Figure 1. The number of amputations per month for the US Military during OEF and OND. The data for the year of 2011 include only data through July 30.

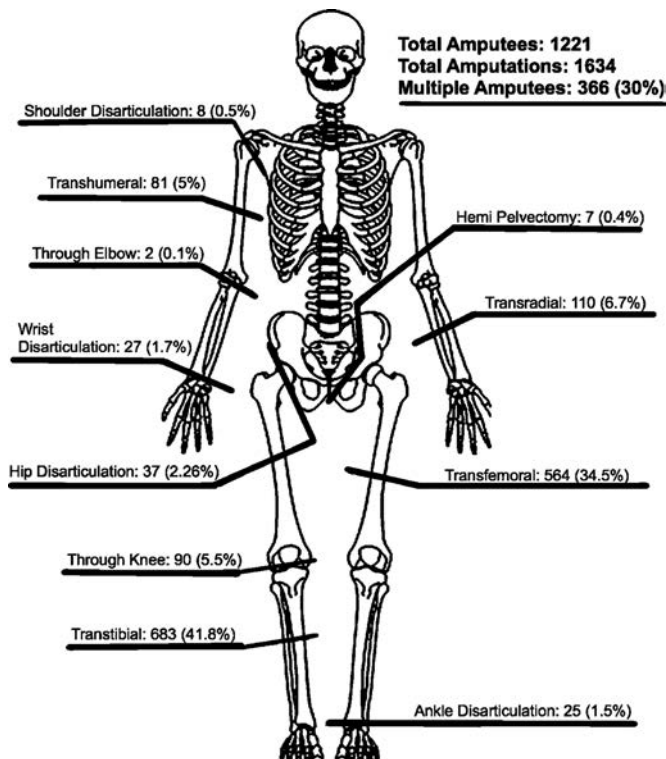


Figure 2. Number of amputations performed at each body location. Percentages show the percent of total amputations that each location represented.

General. Specific deployment numbers for each branch of service before 2005 were not accurately recorded and therefore not used when calculating the amputation rates in this study.

RESULTS

General Characteristics

There were 1,221 amputees who sustained a total of 1,631 major amputations. The number of amputees each year

increased through 2007 before decreasing temporarily and rising again in 2010 and the first half of 2011 (Fig. 1). Of the 39 nonbattle-related amputations, 15 (38%) were caused by an MVA, and 8 (21%) were caused by GSW; 1,136 of the amputees (93.0%) had a primary injury cause of an explosion, whereas 46 (3.7%) were primarily injured by GSW, and 21 (1.7%) were injured by an MVA. The most common injury types were penetrating (978, 76%) and blunt (275, 22.5%) trauma. Most amputees had an ISS between 9 and 25 and an extremity-specific AIS score of 4. The mean ISS for all amputees was 20.7 (median 18). General demographics for the amputees are listed in Supplemental Digital Content 2, <http://links.lww.com/TA/A215>.

More than 75% of all amputations were either transtibial (41.8%) or transfemoral (34.5%). The body locations at which all amputations took place can be seen in Figure 2. More than 80% of amputees underwent their amputation on the same day they were injured (see Table, Supplemental Digital Content 2, <http://links.lww.com/TA/A215>). For those amputations that took place after 90 days (late amputations), the mean number of days between the date of injury and their initial amputation was 473 (median, 367 days; long, 2,019 days). The percentage of injuries that resulted in a late amputation stayed between 11% and 15% from 2003 through 2010 (Fig. 3). Ninety-two Service Members (72.4%) who underwent a late amputation underwent a late transtibial amputation.

Rate of Amputation

The number of amputations that occurred per every 100 trauma admissions to Role IIb or Role III facilities steadily increased throughout the conflicts until a dramatic increase in 2010. Between July 2010 and July 2011, the rate increased from 3.5 to 14. The mean rate of amputation for every 100 trauma admissions during the entire 10 year conflict was 3.6 (see Figure, Supplemental Digital Content 3, <http://links.lww.com/TA/A216>).

The mean amputation rate for the entire conflict was 5.29 per 100,000 deployed troops. During that same timeframe, there was a mean of 18.5 combat deaths per 100,000 deployed troops.

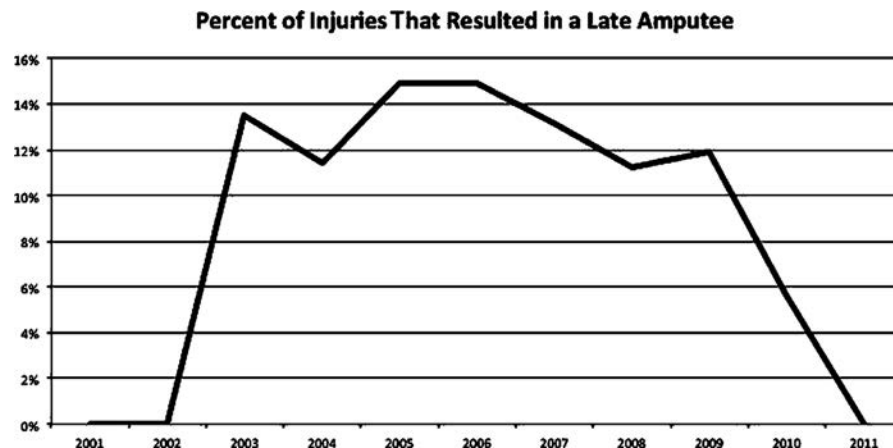


Figure 3. Percentage of late amputees who were injured in each year divided by the number of total number of amputees who were injured in the same year. There were no amputees injured in 2001 and one amputee injured in 2002. The median delay for late amputees was 367 days, meaning that most late amputees who were injured in late 2010 and 2011 would undergo their late amputation in 2012. The data for the year 2011 include only data through July 30.

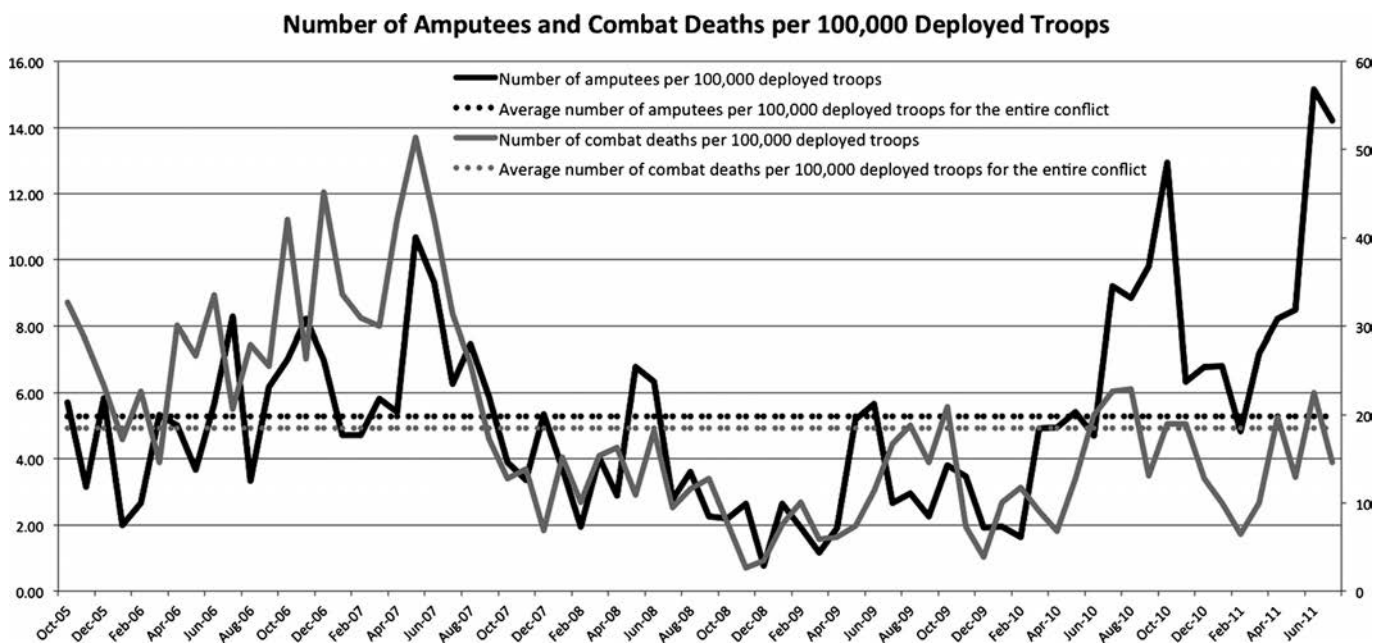


Figure 4. The number of amputees (left axis) and combat deaths (KIA + DOW) (right axis) for every 100,000 Service Members deployed. Combat deaths are calculated by adding those Service Members who are KIA to those Service Members who DOW sustained during combat. The data for the year 2011 include only data through July 30. The dashed lines represent the mean for both values from January 2002 through July 2011.

Both rates had spikes during 2007 and nadirs from 2008 to 2009. However, only the amputation rate seemed to increase sharply in 2010 and the first half of 2011 (Fig. 4).

Multiple and Upper-Extremity (UE) Amputees

There were 366 multiple amputees (30%). The percentage of multiple amputees increased throughout OIF, OEF, and OND and had a sharp rise during 2010 and the first half of 2011 (Fig. 5). The most common multiple amputation pattern was bilateral transfemoral (27%). Table 1 shows the most common combinations of multiple amputees.

There were 218 Service Members (18%) who sustained an UE amputation and 11 amputees (0.9%) who sustained

bilateral UE amputations. As a whole, UE amputations accounted for 228 (14%) of all amputations performed.

DISCUSSION

US Service members serving in OIF, OEF, and OND conflicts have sustained a substantial number of amputations.^{13,16,22} These amputations have been associated with significant rates of heterotopic ossification,²³ infection,²⁴ and soft tissue failure.²⁵ In addition, amputees require a significant amount of treatment resources,^{26,27} and treatment prevents many Service Members from being able to return to their active-duty status.⁷ Previous studies have examined limited collections of these patients with amputations.^{4,6,9,13,17,28–30} Differing study periods examined, patient characteristics, and methods used have made it difficult to gain a comprehensive picture of all amputees from these conflicts. This study attempted to fill that gap by providing an overall characterization of amputees who have been injured during OEF, OIF, and OND.

One of the most evident findings is the relatively well-defined periods of increased amputations: one during 2006 to 2007 and another during 2010 and the first half of 2011. During those peaks, there was an increase in the rate of amputations per 100 traumatic injuries, not just the number of amputations performed. This suggests that an increase in battle-related injuries alone was not the sole reason for the increase in amputations.^{8,31} Two plausible factors for the increase in amputations during these times might be methods used by the US Military and the unique phases of the conflict noted in Supplemental Digital Content 3, <http://links.lww.com/TA/A216>. It is possible that during various surges, withdrawals, and battles US Military forces had an increased exposure to weapons and

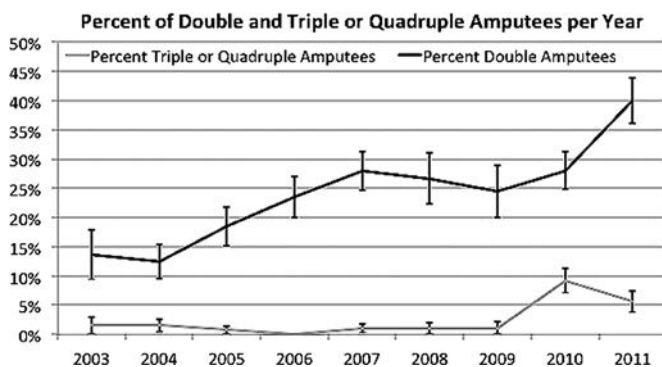


Figure 5. The percentage of all amputees who sustained double or triple/quadruple amputations per year. The data for the year 2011 include only data through July 30. SE of the mean bars are depicted for each data point.

TABLE 1. The Most Common Combinations of Amputations Sustained by the Multiple Amputees

Combinations (Number or Extremities)	No. Amputees	Multiple Amputees, %
(2) Transfemoral, transfemoral	100	27
(2) Transtibial, transtibial	73	20
(2) Transfemoral, transtibial	57	16
(2) Transtibial, knee disarticulation	20	5
(2) Transfemoral, knee disarticulation	16	4
(3) Transfemoral, transfemoral, transhumeral	11	3
(2) Hip disarticulation, transfemoral	10	3
(3) Transfemoral, transfemoral, transradial	8	2
(2) Knee disarticulation, knee disarticulation	8	2
(2) Transfemoral, transhumeral	7	2
(2) Transradial, transradial	5	1
(3) Hip disarticulation, transfemoral, transradial	5	1
(2) Hemipelvectomy, transfemoral	5	1
(2) Transfemoral, transradial	4	1
(2) Transfemoral, hip disarticulation	4	1
(2) Transradial, transtibial	3	1
(2) Transfemoral, transtibial, transradial	3	1
(2) Transfemoral, wrist disarticulation	3	1
(2) Transradial, transtibial	3	1
(2) Transradial, transhumeral	2	1
(3) Transfemoral, knee disarticulation, transradial	2	1
(2) Transtibial, ankle disarticulation	2	1
(2) Hip disarticulation, transtibial	2	1
(2) Hip disarticulation, hip disarticulation	2	1
(2) Transhumeral, elbow disarticulation	1	0
(2) Transhumeral, knee disarticulation	1	0
(2) Transfemoral, ankle disarticulation	1	0
(3) Transtibial, transtibial, transradial	1	0
(3) Transtibial, knee disarticulation, transradial	1	0
(2) Transtibial, shoulder disarticulation	1	0
(3) Knee disarticulation, knee disarticulation, transradial	1	0
(2) Hemipelvectomy, hip disarticulation	1	0
(4) Transfemoral, transfemoral, transhumeral, transradial	1	0
(4) Transfemoral, knee disarticulation, transhumeral, transradial	1	0
(4) Knee Disarticulation, knee disarticulation, elbow disarticulation, wrist disarticulation	1	0
Total	366	30 (of all amputees)

injuries that could have led to an amputation. Less obvious events, such as changing vehicles to Mine Resistant Ambush Protected vehicles (MRAPs) for troop patrol during late 2007 and then dismounted operations in Afghanistan in 2010, may have also contributed to the rate changes in amputations.

The mean ISS for all amputees, 20.7, is lower than that described by Morrison et al.²⁹ in their review of injuries caused by improvised explosive devices (28) but higher than the mean ISS found by Gwinn et al.³² for both the acute (10.1) and delayed (18.8) amputees. The mean ISS for our female amputees was 18.8. This value is between the mean of 10.7 found for battle injuries not leading to death and the mean ISS

of 24.5 in those females who were KIA or DOW found in a previous study.²¹

Although most of the amputations were documented as occurring within the same day as the initial injury (82%), there were 127 amputees (10%) who underwent their amputation more than 90 days after the date of injury. This percentage of late amputations is lower than most previous reports (see Table, Supplemental Digital Content 4, <http://links.lww.com/TA/A217>). The mean delay after injury for the late amputees was 473 days (median, 367 days). These values are lower than what has previously been reported by Stinner et al.³³ in their cohort of 53 Service Members. However, the percentage of officers (19%) who underwent late amputations in this study compares favorably with the percentage reported by Stinner et al. (17%). Figure 3 shows that the percentage of injured Service Members that result in a late amputation has remained relatively stable. This suggests that the medical personnel who are initially caring for the injured Service Members have been consistent in determining which limbs should undergo an acute amputation and those that should undergo an attempted salvage.

The most common cause of injury to lead to an amputation was an explosive device (93%). This finding is not surprising, considering that explosive weapons can be used in almost any part of the battlefield,²¹ are extremely high energy,⁴ cause massive soft tissue damage,^{34,35} and are the mechanism of injury that accounts for the greatest number of combat injuries and deaths.^{4,29,31,34} It may be in part because explosive devices accounted for such a large portion of amputations that lower-extremity (LE) amputations were much more common than UE amputations as most of these explosive devices are at, or close to, the ground level.

As Belmont et al.³¹ noted, it is difficult to perform meaningful comparisons between rates established between studies because of differences in calculation, variation in definitions and populations used. Potter and Scoville¹⁶ described an amputation rate of 2.3% for all "combat wounds," while Stansbury et al.¹³ described an amputation rate of 5.2% for "all serious injuries." Although higher rates of amputation have been reported when looking at the rate of amputation for all Service Members injured by an explosive device,²⁹ the rate of 3.6 amputees for every 100 traumatic admissions to Role IIb and III facilities found by this study seems to correlate well with previously described rates. The authors could not find literature to compare the rate of 5.29 amputees for every 100,000 deployed troops against. However, it is important to remember that not all deployed troops have an equal risk to combat injury,²⁶ meaning that certain groups of Service Members (i.e., Infantry and Marines) likely have a higher rate of amputation per deployed troops than others.

Analysis of the amputation levels showed that more than 40% of all amputations were transtibial and almost 35% were transfemoral. These results correlate with previous studies showing that transtibial and transfemoral amputations are the primary amputations performed on injured Service Members.^{13,29,33} The relative lack of knee disarticulations (5.5% of all amputations) may be because of the reported poor long-term results that the LEAP study group showed with through-knee amputations compared with transtibial and

transfemoral.³⁶ These results were published before most amputations were performed during the OIF, OEF, and OND conflicts and may have influenced the treating surgeons' decision making. However, only 29 of the 90 knee disarticulation were performed as an isolated limb amputation (32%). This percentage was much less than the 443 transtibial amputations (65%) but similar to the 196 transfemoral amputations (35%) performed in isolation. These data suggest that knee disarticulations are performed at a similar rate as transfemoral amputations for isolated limb injuries and that the overall absence of through-knee amputations may have more to do with the injury severity of the Service Members than with surgeon decision making.

Only 14% of all amputations occurred in the upper extremities, a percentage that differs from reports by Stansbury et al.¹³ and Potter and Scoville¹⁶ who showed that close to 25% of all amputations involved the UE. Even more opposing results were noted by Dougherty et al.,¹⁹ who found that 50% of all extremity amputations occurred in the UE. It may be that LE injuries are more severe or life threatening than UE injuries,¹⁹ forcing surgeons to amputate the limb to save the Service Member's life as opposed to attempt limb salvage.^{19,35} The disparity between the number of UE and LE amputees, especially bilateral UE amputees, may further be influenced by the conventional teaching that upper-limb salvage yields improved outcomes over amputation. The percentage of bilateral UE amputees in this study (5.0%) is similar to the 5.7% of UE amputees who sustained bilateral amputations reported by Stansbury et al.¹³ However, this percentage is significantly less than the 21% of LE amputees who sustained bilateral LE amputations (295). The percentage of UE amputations that occurred either as transradial or transhumeral amputations (83.7%) was very similar to the percentage of LE amputations that were performed at the transtibial or transfemoral level (88.7%).

This study found that 30% of all amputees had multiple amputations, most of which involved the LE. This percentage is higher than all but one previously published report (see Table, Supplemental Digital Content 5, <http://links.lww.com/TA/A218>) and much higher than the 2% to 20% multiple-amputee rate reported from World War I, World War II, the Korean War, and the Vietnam War.^{13,16} One of the reasons for these differences may be that previous studies of the OIF and OEF conflicts examined earlier years than this study. Doing so would have led these studies to miss the large number of the multiple-extremity amputations that occurred in 2010 and the first half of 2011 (Fig. 5). It is also likely that medical personnel have become more adept at saving the lives of injured Service Members in the OIF and OEF conflicts, leading to a larger number of surviving Service Members with multiple amputations.

Like previous studies,^{6,29} this study found that most multiple amputees had bilateral LE amputations. Morrison et al.²⁹ found that proximal leg amputation was associated with reduced survival among Service Members and that bilateral transfemoral amputations were the point at which more troops than not were able to survive their injury. Although this study did not examine survival patterns, it may be because of a decreased survival rate among the hip disarticulations and hemipelvectomy amputees that there were so few of these

amputations in this study compared with transfemoral amputations. Previous reports had shown a mortality rate of 100% in Service Members who sustained bilateral hip disarticulation.²⁹ This study found two Service Members with bilateral hip disarticulation and one Service Member with a hip disarticulation and contralateral hemipelvectomy. These findings are a testament to the acute care provided to the wounded warriors, which has helped increase their survival rate from severe injuries.

One of the biggest strengths of this study lies in its size. The cohort of amputees used in this study is far greater than previous studies that have examined the amputees of the OIF and OEF conflicts.^{13,16,18,28,29,33} However, this study has a number of limitations. First, it is a retrospective study that compared reported data from multiple databases and registries, some of which was recorded during chaotic periods of combat, likely leading to reporting errors. In addition, some of the data from these multiple locations was not congruent, and therefore, trends are more likely to be representative of the true data than the exact numbers reported. This study also only examined initial MEAs. Therefore, if a Service Member had a partial hand or foot amputation initially, he was not included in these data. Furthermore, if a Service Member had a partial hand or foot amputation that was later revised to an MEA level, it was not captured in this study. This limitation may cause this study to present a more optimistic picture of the amputations that have occurred during OIF/OEF than what has actually taken place. Another limitation of this study is that we do not have any follow-up data on the amputees and we do not know what associated injuries these Service Members sustained. Both pieces of information are vital for determining the short- and long-term effects these amputations have on our Military forces and how to best provide care to our wounded warriors. Lastly, this article did not look at the specific differences between amputees of different service branches. However, the authors are currently investigating this question.

CONCLUSION

This retrospective study agrees with most previous studies that have examined the amputees from the OIF, OEF, and OND on many levels. However, this study suggests that multiple amputations and LE amputations make up a much higher percentage of amputations than previously reported. It also highlights the recent increase in amputees sustaining multiple amputations during 2010 and the first half of 2011, in addition to the increased number of amputations occurring during that period. This study provides a very large overview of the amputations that have taken place during the OIF, OEF, and OND conflicts, providing a platform from which further questions can be examined.

AUTHORSHIP

The following are the contributions each author had for this article. C.A.K. contributed efforts in the study design, literature search, data collection, data analysis/interpretation, figure composition, table composition, writing, and revisions. J.C.W. was an integral part of the study idea, study design, reference literature, data analysis/interpretation, figure and table composition, and critical revisions and editing of the

article. J.R.F. contributed in the study idea, study design, data analysis/interpretation, figure and table composition, critical revisions, and editing of the article.

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DISCLOSURE

The authors declare no conflicts of interest.

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